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# Soil Resource Draft Report

## Medicine Bow LaVA Project

Medicine Bow National Forest

Albany and Carbon Counties, Wyoming

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Date

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## Introduction

This report documents existing conditions and analyzes potential environmental effects to soil resources, related to the proposed Medicine Bow Landscape Vegetation Analysis Project (LaVa). The report also includes project design features and specific Best Management Practices that would be required to be implemented as part of this project.

## Relevant Laws, Regulations, and Policy

### Regulatory Framework

#### Land and Resource Management Plan

The following Standards and Guides for soil resources to the LaVa project as listed in the 2003 Revised Land and Resource Management Plan for the Medicine Bow National Forest. These standards are also Region R2 FSH (Watershed Conservation Practices Handbook) management measures 13.1 through 13.4 (Sediment Control) and 14.1 and 14.2 (Soil Quality).

#### *Standards*

1. Limit roads and other disturbed sites to the minimum feasible number, width, and total length consistent with purpose of specific operation, local topography, and climate.
2. Construct roads and other disturbed sites to minimize sediment discharge into streams, lakes, and wetlands.
3. Stabilize and maintain roads and other disturbed sites during and after construction to control erosion.
4. Reclaim roads and other disturbed sites when use ends, as needed, to prevent resource damage.
5. Manage land treatments to limit the sum of severely burned and detrimentally compacted, eroded, and displaced land to no more than 15% of any activity area.

The 15% limit applies to all natural and human disturbances that may impact soil structure, organic matter, and nutrients in areas allocated for vegetation production. Where excessive soil impacts already exist from prior activity, the emphasis should be on preventing any additional detrimental impacts and on reclamation where practicable. [R2 2509.10]

6. Maintain or improve long-term levels of organic matter and nutrients on all lands.

#### *Guidelines*

1. Prohibit soil-disturbing activities (e.g., road construction, wellpad construction) on slopes greater than 60% and on soils susceptible to high erosion and geologic hazard.
2. Perform an on-site slope stability examination on slopes over 40% prior to designing roads or activities that remove most or all of the timber canopy. Limit intensive ground-disturbing activities on unstable slopes identified during the examinations.

No soil resource specific direction exists in the applicable Management Area direction. Forest Plan Standards for the protection of the soil resource apply to all management areas.

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### *National Forest Management Act*

The National Forest Management Act (NFMA) of 1976 recognized the fundamental need to protect, and where appropriate improve, the quality of soil, water, and air resources. With respect to soils, NFMA requires that the Forest Service manage lands so as not to impair their long-term productivity. Further, activities must be monitored to ensure that productivity is protected. This law led to subsequent regulation and policy to execute the law at various levels of management.

The National Forest Management Act (NFMA) (16 U.S.C. 1604) states that “timber harvested from National Forest System lands...only where soil, slope, or other watershed conditions will not be irreversibly damaged.” Forest plans will “insure...evaluation of the effects of each management system to the end that it will not produce substantial and permanent impairment of the productivity of the land.”

### *National Soil Management Manual - 2550*

The National Soil Management Handbook defines soil quality and components of soil function, and establishes guidance for measuring soil quality using indicators.

Management activities have potential to cause various types and degrees of disturbance. Soil disturbance is categorized into compaction, displacement, puddling, severe burning, and erosion. Direction was established that properties, measures, and thresholds relative to these disturbance types would be developed at the Regional and Forest levels, known as Soil Quality Standards.

### *Forest Service Handbook, Region 2 - Soil and Water Conservation Practices*

This chapter describes the policies and objectives relevant to soil and water conservation practices, the practices themselves and directs the Forest Service to implement these measures as a means of preventing or mitigating.

### *National Core Best Management Practices*

The National Core Best Management Practices (BMP) are intended for use on National Forest System Lands (NFS) as part of the Forest Service strategy for water quality management. The purpose of the National BMP program is threefold

1. To establish uniform direction for BMP implementation to control nonpoint source pollution on all NFS lands to avoid, minimize, or mitigate adverse effects to soil, water quality, and riparian resources that will meet the intent of the Federal and State water quality laws and regulations, Executive orders, and USDA and Forest Service directives
2. To establish a consistent process to monitor and evaluate forest Service efforts to implement BMPs and the effectiveness of those BMPs at protecting water quality at national, regional, and forest scales.
3. To establish a consistent and credible process to document and report agency BMP implementation and effectiveness.

## Topics and Issues Addressed in This Analysis

### **Purpose and Need**

The purpose of the LaVA Project is to respond to changed forest vegetation conditions presented by the bark beetle epidemics experienced on the MBNF. The need for the project is defined by existing and predicted trends in vegetation conditions and the threats to forest values they pose. The approach is to

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actively manage forest vegetation using tree cutting, prescribed burning, or hand treatments, consistent with the goals outlined in the Governor's Task Force on Forests (Final Report, 2015), Western Bark Beetle Strategy (July 2011), Wyoming Statewide Forest Resource Strategy (2010), the Healthy Forests Restoration Act and Farm Bill Amendment (2003 and 2014), and Medicine Bow Forest Plan (2003). Goals include promoting recovery from the insect infestations, improving the resiliency of green stands to future disturbances, helping protect forested areas on adjacent private and state land, and providing for human safety. General goals will be adapted during implementation to fit conditions at the local project scale where treatments are needed based on Forest Plan direction, foreseeable conditions, and local environmental, social and economic concerns.

The project purposes are in bold below, followed by bulleted statements describing the project needs:

**Enhance Forest and Rangeland Resiliency to Future Insect and Disease Infestations:**

1. Increase age class, structural, and vegetative diversity across the landscape
2. Promote forest and rangeland conditions to improve forage and wildlife habitat
3. Actively accelerate recovery and regeneration of forest ecosystems

**Provide for Recovery of Forest Products:**

4. Promote vegetation management to recover merchantable products
5. Provide commercial forest products to local industries at a level commensurate with Forest Plan direction and goals

**Provide for Human Safety:**

Treat hazard trees in areas not covered by the Forest-wide Hazard Tree Decision Notice (August 12, 2008);

6. Treat hazard trees within and outside the wildland urban interface (WUI)
7. Increase the extent of defensible space around resources at risk
8. Create fuel breaks to slow or stop the progress of wildfires

**Provide for Protection of Infrastructure, Municipal Water Supplies, and Threatened and Endangered Species Habitat:**

9. Treat vegetation adjacent to infrastructure and non-federally owned lands
10. Treat vegetation to protect municipal water supplies and infrastructure
11. Treat vegetation where fire is identified as a threat to the habitat of a threatened or endangered species

**Mitigate Hazardous Fuel Loading:**

12. Treat hazardous fuels to minimize the potential for large, high intensity/high severity wildfires
13. Treat hazardous fuels to reduce fire behavior and the possibility of fires spreading onto adjacent, non-federal lands

**Project Area**

The project area encompasses approximately 615,230 acres of National Forest System (NFS) lands and 150,000 – 350,000 vegetation treatment acres located in Albany and Carbon counties in South Central Wyoming. Proposed activities would occur on NFS lands managed by the Medicine Bow National Forest, Laramie and Brush Creek/Hayden Ranger Districts. For purposes of analyzing the Proposed Action, the

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project area is divided into 14 Accounting Units which are discussed in more detail in Chapter 2 of the EIS.

### **Brief Description of Proposed Action**

The Forest Service proposes to conduct vegetation management activities on NFS lands, including inventoried roadless areas, within the Sierra Madre and Snowy Range Mountain Ranges of the Medicine Bow National Forest. The Notice of Intent for the LaVA EIS described that vegetation management activities, including prescribed fire, mechanical, and hand treatment methods, could be applied to 150,000 – 350,000 acres within the designated Treatment Opportunity Areas (615,230 acres) to protect, restore and enhance forest ecosystem components; reduce wildfire risk to communities and municipal water supplies; supply forest products to local industries; and improve, protect, and restore wildlife habitat.

### **Resource Concerns**

Impacts to the soil resource from the proposed action are a resource concern. Treatment areas that require use of ground based mechanical equipment such as harvest activities, landing construction, temporary road construction, skid trails, and mastication treatments are potential areas of increased soil disturbance (compaction and rutting), soil displacement, and surface organic matter removal. These ground disturbing activities can reduce infiltration, increase runoff erosion, and change organic matter impulse to the soil. Prescribed burning and burn piles have the potential to create areas of severe soil burning, causing loss of soil physical, biological, and chemical functions and a decrease in organic matter needed for future soil nutrient stores.

### **Issues**

Soil erosion and compaction has been brought as direct issues for the soils resource area.

### **Resource Indicators and Measures**

Effects to the soil resource are evaluated in terms of conditions that would promote loss of soil and its ability to carry out particular ecological functions. Effects will be disclosed in terms of detrimental disturbance predicted or anticipated from the various types of proposed treatment activities (Table 1). Detrimental disturbances are those processes which can alter or destroy the ability of soils to support communities of native plants and consist of compaction, puddling, and displacement (erosion) of mineral soil, and the displacement or destruction of litter, duff, and large woody debris.

Soil quality determines vegetation growth capability in all terrestrial ecosystems. Soil depth, structure, organic matter, and nutrients are critical to sustaining this potential. Management measures and design criteria to protect soil quality apply to all actions that may impact these soil qualities. [R2 2509.10] Soil quality indicators are used to assess soil functions. Most soil quality indicators are observations and measurements taken at the soil surface and in the upper mineral soil. The condition at the soil surface and in the upper mineral soil strongly influences soil hydrology, biology, carbon sequestration, nutrient cycling, soil stability and support functions and in turn, long term soil productivity and ecosystem processes and functions.

It is important to realize that soil functions are interrelated with each other, as well as with other ecosystem functions. Understanding these interrelationships is essential to accurate interpretation of soil quality. Soil quality indicators are developed to give insights as to how well the inherent soil is functioning, i.e., biologically, hydrologically, carbon storage, etc. The ultimate goal of the soil quality indicators is to provide information on the health of the soil [FSM 2500-2010].

Resource indicators and measures are listed in Table 1. A Wetness Index Rating Model will be one indicator. It helps to display areas in the project area where temporary road building and landing construction will be problematic due to compaction and erosion issues. It can also be used for identifying other areas across the project area that may be problematic, such as vegetation treatments where mechanical harvesting and mastication equipment are driven cross-country.

**Table 1. Resource Indicators and Measures**

<b>Resource Element</b>	<b>Resource Indicator</b>	<b>Measure</b>	<b>Used to address: P/N, or key issue?</b>	<b>Source (LRMP S/G; law or policy, BMPs, etc.)?</b>
Soil Quality Soil Productivity	Soil Condition	Inherent Wetness Index Model	No	NFMA, LRMP
Soil Quality Soil Productivity Soil Stability	Erosive Soils	Severe erosion hazard Severe mass wasting	No	NFMA, LRMP
Soil Quality Soil Productivity	Organic Matter Soil Condition	Shallow soils	No	NFMA, LRMP

## Methodology

The analysis method is to present the existing conditions for soil resources, describe soil resources within the project area, present information on potential effects of the treatments, and present recommended mitigation measures and design features. A field review for the soil resources was not available so the following data sources were used to evaluate the soil resources within the project area:

- Medicine Bow National Forest corporate Geographic Information System (GIS) data
- Medicine Bow National Forest corporate Soil data
- Inherent Wetness Model (IWM)

There are seven primary inputs in determining the inherent wetness of the forested landscapes, which determine a rating of 1-10. These seven factors are:

1. Erosion Hazard Rating
2. Depth to Restrictive Layer
3. Hydrological Soil Group (HSG)
4. Aspect Class
5. Slope Class
6. Existing Vegetation Type (EVT)
7. Solar Radiation

Areas with a rating of “5” are seasonally wet. Areas above a “6” ratings are most susceptible to compaction and erosion if they are hydrologically connected to a stream. The model gives a good ballpark representation of wetness across the landscape. This model is further discussed in a white paper in the project file (Overland 2017).

The effects analysis contained in this report was produced under the key assumption that all standards and guidelines, standard operating procedures, project specific design features, mitigations, and contract

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provisions will be fully adhered to and implemented, including the use of the appropriate Best Management Practices (BMPs).

## Incomplete and Unavailable Information

Spatial locations of temporary roads proposed for the project were not available for this analysis. Spatial locations for treatment areas were not available for this EIS but will be developed when a project is brought forward for analysis within the LaVa analysis area.

## Spatial and Temporal Context for Effects Analysis

The spatial boundaries for analyzing the direct, indirect, and cumulative effects to the soil resource are the 14 Accounting Units that make up the project area. Soil productivity is a site-specific characteristic and is typically assessed within an activity area. However, for this larger landscape analysis the 14 Accounting Units, identified in greater detail in the EIS, will be used to assess soil resources.

The temporal scale for assessing soil resource environmental effects includes both short- and long-term impacts. For the purposes of this analysis, short-term effects are defined as those that occur within about 10 years following proposed vegetation treatments. Long-term effects are defined as those that occur within about 10 to 20 years or more following proposed vegetation treatments.

## Affected Environment

### Existing Condition

The current condition of the soil resource is dependent upon natural soil characteristics, past and present uses, past and present management activities, and natural events. The effects to the soil resource are discussed as potential changes in long-term *soil quality*.

*Soil quality* can be regarded as the capacity of the soil to perform the functions necessary for its intended use while continuing to provide important ecosystem services. More than just a medium for plant growth, healthy soils cycle and retain nutrients, partition water and soluble materials, and buffer and break down contaminants. Healthy soils resist the erosive forces of water and wind and maintain good structure and aggregate stability, which allows water to infiltrate and improves soil water holding capacity.

Some disturbance is natural. Wildlife, treefall, drought, fire, and floods are among the many factors that disturb the soil. Some of these disturbances help maintain soil functions, while others degrade them. Healthy soils are *resistant to* and/or *resilient from* degradation. Resistance is the ability of the ecosystem to continue to function without change when stressed by disturbance. Resilience is the ability of the ecosystem to recover after disturbance (Herrick and Wander, 1998; Seybold et al., 1999). A resistant and resilient ecosystem is essential for sustainability.

*Response to disturbance* depends on soil properties and the frequency, intensity, and type of disturbance. Practices can disturb the soil in ways that overwhelm the soil's resistance and resilience. Within the constraint of climate, a site's potential productivity is governed by physical, chemical, and biological soil characteristics and processes. Soil disturbance to any one of these processes can decrease long-term soil productivity and thereby reduce soil quality and ecosystem health. Physical characteristics include soil structure, texture, clay content, bulk density, and porosity. Physical processes such as erosion and infiltration rates change soil physical characteristics. Chemical characteristics include organic matter, carbon, nitrogen, cation exchange capacity, and pH. Chemical processes such as weathering of rocks and nutrient additions and losses contribute to soil development and nutrient availability to plants. Biological soil characteristics include living organisms that inhabit the soil. Biological processes such as

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decomposition, nitrogen cycling, soil stabilization, and plant nutrition contribute to soil productivity (Forest Service, 2005).

Soil quality can be evaluated in terms of conditions that would promote loss of soil and its ability to carry out particular ecological functions. Effects frequently are disclosed in terms of detrimental disturbances that have occurred within the activity area and are predicted or anticipated from the various types of proposed treatment activities. Possible past and current activities that could have an impact on the soil resource include timber harvest activities, grazing, road and trail construction, mining, and recreation.

### Soil Standards 1 thru 4 (Roads)

Forest plan (and Regional soil standards) 1 thru 4 are focused on the impact of roads on the soil resource. The four primary disturbances to soils from roads are compaction, displacement, puddling, and erosion. The inherent wetness across the forested landscape has a direct influence on these four soil disturbances with respect to road locations. There are seven primary inputs in determining the inherent wetness of the forested landscapes as stated above.

### *Erosion Hazard Rating (EHR)*

Erosion hazard is the inherent susceptibility of a soil to erosive forces such as raindrop impact or overland flow and is dependent on particle size distribution, organic matter content, soil structure, permeability, rock fragment content, slope gradient, and rainfall characteristics. These ratings are based on the risk of soil loss after disturbances that result in 50 to 75 percent exposed, roughened mineral soil. These hazards are defined as follows:

**Table 2. Erosion Hazard Ratings**

<b>EHR Rating</b>	<b>Acres</b>	<b>Percentage</b>
None	36,913	4
Slight	295,027	32
Moderate	546,358	60
Severe	35,987	4
Not Rated	1,883	0
Total	916,154	100

- *Slight* – Little or no erosion is likely under normal climatic conditions.
- *Moderate* – Some erosion is likely; occasional maintenance may be needed; simple erosion control measures needed.
- *Severe* – Significant erosion can be expected; roads require frequent maintenance; costly erosion measures are needed (USDA Forest Service 2003b) (Table 2).

### *Depth to Restrictive Layer*

The Natural Resources Conservation Service (NRCS) classifies the term “depth to restrictive layer” as a continuous layer that has one or more physical, chemical, or thermal properties that significantly slow the movement of water and air through the soil or that restricts root movement through the soil. Examples of restrictive layers are bedrock, cemented layers, or frozen layers (Table 3).

**Table 3. Depth to Restrictive Layer Ratings**

Depth to Restrictive Layer	Rating	Acres	Percentage
Less than 20	Severe	83,054	9
20 to 40	Moderate	1,882	0
40 to 60	Slight	118,304	13
Greater than 60	None	711,045	78
Not Rated	Not Rated	1,869	0
Total		916,154	100

**Hydrological Soil Group (HSG)**

NRCS defines HSG as the hydrologic parameter in determining runoff for an individual storm for a bare soil after prolonged wetting. There are four HSG groups:

Group A- Soils having high infiltration rates even when thoroughly wetted. Low runoff potential.

Group B – Soils having moderate infiltration rates when thoroughly wetted.

Group C – Soils having slow infiltration rates when thoroughly wetted.

Group D – Soils having very slow infiltration rates when thoroughly wetted. High runoff potential (Table 4).

**Table 4. Hydrologic Soil Group Ratings**

Hydrologic Soil Group	Rating	Acres	Percentage
A	Low	607,688	66
B	Moderate	236,103	26
C	High	1,801	0
D	Severe	68,675	7
Not Rated	Not Rated	1,868	0
Total		916,135	100

Water will infiltrate into soil at different rates when wet due to different soil properties. Slow infiltration rates, such as groups C and D, can cause increased runoff erosion since water cannot seep into the ground. In timber harvest units groups C and D would be potential areas of increased compaction and erosion.

**Aspect Class**

Northeast aspects are the wettest on the landscape and the southwest is the driest. Roads have more maintenance issues and costs on the wetter aspects in the landscape. Southwest aspects would be areas of concern during prescribed burning activities as these aspects are warmer with drier vegetation (Table 5).

**Table 5. Aspect Class Summary**

<b>Aspect Class (Degrees)</b>	<b>Apparent Wetness</b>	<b>Acres</b>	<b>Percentage</b>
315 to 45	Wettest	251,402	27
45 to 135	Moderately Wet	213,508	23
135 to 225	Driest	239,975	26
225 to 270	Moderately Dry	211,246	23
Total		916,135	100

*Slope Class*

Steeper slopes have a quicker runoff response to rainstorms. Table 6 shows the summary of slope class in the LaVa project area.

**Table 6. Slope Class summary**

<b>Slope Class (Percent)</b>	<b>Apparent Wetness</b>	<b>Acres</b>	<b>Percentage</b>
Less than 5	Low	104,887	11
5 to 35	Moderate	694,837	76
35 to 65	High	109,291	12
Greater than 65	Severe	7,123	1
Total		916,138	100

*Existing Vegetation Type (EVT)*

Vegetation types are an indicator of wetness on the landscape. The existing vegetation type raster layer from LandFire designates vegetation types from LandSat imagery. The SAF-SRM column is used to create a wetness rating based on root structures. Table 7 shows the summary of existing vegetation type in the LaVa project area.

**Table 7. Existing Vegetation Type Summary**

<b>SAF-SRM Type</b>	<b>Apparent Wetness</b>	<b>Acres</b>	<b>Percentage</b>
Conifer Types	Driest	342,925	37
Hardwood Types	Drier	8,283	1
Developed, barren and sparse types	Moderately Dry	5,865	1

Pinyon, chaparral and sagebrush types	Moderately Dry	86,225	9
Grasslands	Wet	28,378	3
Wet Conifer Types (lodgepole pine)	Wet	229,883	25
Wet Forest types (aspen, cottonwood)	Very Wet	209,237	23
Water	Wettest	5,340	1
Total		916,135	100

### *Solar Radiation*

Annual solar radiation is an indication of how much sunlight hits the landscape. Ridges tend to have the most solar radiation and steeper canyons receiving the least solar radiation. Solar radiation has an impact on the amount of surface soil moisture during the year. Annual solar radiation is calculated in GIS using a digital elevation model (DEM).

### *Inherent Wetness Model (IWM)*

The IWM model rates each factor on a scale of 10 to 99 (dry to wet), creates a composite layer from all seven factor layers (rated), and the composite score is grouped into one of 10 categories (Table 8). The composite score in the LaVa Project are range from a low of 85 to a high of 460 with an average of 226. (a “White Paper” is located in the project file for description of the IWM model by Overland 2017).

**Table 8. Inherent Wetness Model Rating Categories**

<b>Composite Raster Score</b>	<b>Wetness Index Rating Score</b>
0 to 100	1
100 to 150	2
150 to 200	3
200 to 250	4
250 to 300	5
300 to 350	6
350 to 400	7
400 to 450	8
450 to 500	9
500 and up	10

The Inherent Wetness Model (IWM) is a tool that can be used to assess existing wet and dry land conditions across a landscape. For this project it is used, in part, to identify areas where road construction may or may not be appropriate or may need additional design criteria to protect the soil (FP soil standards 1-4). It can also be used to identify areas that could be susceptible to increased soil disturbances such as compaction and rutting during harvest activities. Or identify areas that are drier which could create soil impacts during prescribed burning (FP soil standards 5 and 6).

IWM rates each of the above seven classes (EHR, depth to restrictive layer, HSG, aspect, slope, existing vegetation, and solar radiation) which are used to generate a Wetness Index Rating Score of 1-10 (driest to wettest). For example, scores of 1 and 2 represent the driest sites across the landscape. These are, generally, well drained soils on gentle slopes with a southern aspect and conifer vegetation types. Scores greater than or equal to five represent increasingly wetter sites on the landscape with poor drainage on northeastern aspects with a wet vegetation types (Overland, 2017). Recent fieldwork on the Lassen NF and Tahoe NF during the 2017 field season indicates that roads may have drainage issues, under size culverts, and most susceptible to culvert failures with scores greater than or equal to five. Table 9 shows the summary by Wetness Index Rating Scores for the LaVA Project Area.

**Table 9. Wetness Index Rating Scores for the LaVa Project Area**

Wetness Index Rating	Acres	Percentage
1	10,011	1
2	99,868	11
3	268,315	29
4	308,114	34
5	166,504	18
6	49,283	5
7	9,921	1
8	2,211	0
9	92	0
Total	914,319	100

### *Road Segment Analysis of Existing Transportation Network*

The road core GIS layer that contains the INFRA database was intersected with a 0.25 mile by 0.25 mile grid to create a road segments layer. This road segments layer was buffered by 100 feet. Spatial statistics analysis of this buffered road segments layer using the TEUI toolbar was completed and the summary is listed in Table 10.

**Table 10. Road Segment Analysis Summary**

Wetness Index Rating Score	Maintenance Level 1 (Closed)	Maintenance Level 2 (High Clearance Vehicles)	Maintenance Level 3 (Suitable for Passenger Cars)	Maintenance Level 4 (Moderate Degree of User Comfort)	Maintenance Level 5 (High Degree of User Comfort)	Non NFS Road	Total Miles
1	8.81	12.12	3.04	1.13	0.09	0.00	25.19
2	138.22	120.24	28.73	19.34	13.05	0.05	319.53
3	387.97	537.41	118.15	78.62	39.83	5.00	1,16.98
4	519.23	561.57	182.28	92.36	16.70	4.42	1,376.56
5	167.82	173.41	50.89	25.02	1.28	0.79	419.21
6	17.25	11.78	3.14	2.39	0.00	0.10	34.67

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7	1.09	0.47	0.00	0.00	0.00	0.00	1.56
Not Rated	12.46	13.91	2.37	220.47	0.38	0.19	30.91
Total	1,252.75	1,430.90	388.61	220.47	71.33	10.55	3,374.61

A total of 455 miles (13.50 percent) are within WIR categories 5 and above, which are considered wet soil types. This subset of roads will be the most susceptible to road drainage issues and increased maintenance cost. A total of 186 miles of this subset is currently on Maintenance Level (ML) 1 or closed roads. These roads may be reopened as part of the LaVa project.

### Soil Standard 5 – 15 Percent Detrimentially Disturbed Soils and Soil Standard 6 – Maintain or improve long-term levels of organic matter and nutrients on all lands

#### *Equivalent Clearcut Area*

On a landscape scale, the equivalent clearcut area (ECA) cumulative watershed effect model serves as a tool to help determine existing conditions of soil resources and to address soil standards five and six. Typically this tool is not used to assess soil resource concerns. However, due to the scale of this EIS it can be used to help identify areas, at a watershed scale, where potential soil concerns are located. The ECA watershed effects model takes all land management activities (timber harvesting, road building, and ski areas) and fire history into account. Each activity is assigned a number on how close it represents a clearcut stand on a basal area standard. The recovery time in the ECA model is based on an 80 year period and all activities are set to this recovery time. The model was run at the 6<sup>th</sup> level HUC watershed scale. An ECA percent of NFS lands over a value of 25 percent is considered over the threshold of concern (TOC) and a field survey would be required before management activities are initiated in these watersheds to determine watershed health. The Hydrology report contains a more in depth analysis of ECA.

There are 66 subwatersheds in the LaVA project area. No subwatersheds are currently over the 25 percent threshold of concern based on modeling results. Although below the threshold, *Spring Creek-Big Creek and East Fork Medicine Bow River* subwatersheds had ECA's of 20%. Used in the context of this analysis, an ECA of 20% points to a higher level of past and current management activities. The concern with the higher level of management activities would be increased levels of erosion, compaction, rutting, and lack of organic matter and soil nutrients beyond the soils ability to remain productive. It however does not indicate that 20% of the area has detrimental soil disturbance. Site reviews prior to and after project implementation should be conducted to ensure that the 15% detrimental soil threshold would not be exceeded and that organic matter and nutrients would be maintained or improved.

#### *Watershed Condition Assessment*

Another useful tool to assess the existing condition of soil resources within the project area is the Watershed Condition Assessment. This was a forest wide assessment conducted at the 6<sup>th</sup> level HUC with 12 indicators used to assess each watershed located on the Medicine Bow National Forest. Soil attributes addressed alteration to natural soil condition, including productivity, erosion, and chemical contamination. Again, this is typically not used to assess soil conditions but due to the scale of this EIS it can be used to aid in identifying areas where potential soil concerns are located at a watershed scale. Within the project area all 6<sup>th</sup> level HUC watersheds were rated as Functioning Properly, except for *Camp Creek and Little Snake River-Whiskey Creek*, which rated as Functioning at Risk. These two watersheds

would have the most acres of detrimentally disturbed soil due to past activities. This assessment also reviews soil nutrient and organic matter processes which addresses Soil Standard 6 – Maintain or improve long-term levels of organic matter and nutrients on all lands. Implementing projects within these two watersheds could benefit soil resources and change the soil rating to Functioning Properly if implemented per project BMPs and design criteria. Projects also have the potential to move these watersheds toward Impaired Function if soil resources are not taken into account during project implementation. These two watersheds should be surveyed prior to project implementation to ensure that the 15% threshold would not be exceeded and that organic matter and nutrients would be maintained or improved (Table 11).

**Table 11. Condition rating rule set and rating for soil condition**

<b>Soils Condition Indicator</b>	Minor or no alteration to reference soil condition, including erosion, productivity, and chemical characteristics is evident.	Moderate amount of alteration to reference soil condition is evident. Overall soil disturbance is characterized as moderate.	Significant alteration to reference soil condition is evident. Overall soil disturbance is characterized as extensive.
<b>Attributes</b>	<b>Class 1- Good – Functioning Properly</b>	<b>Class 2 – Fair – Functioning at Risk</b>	<b>Class 3 – Impaired Function</b>
<b>Soil Productivity</b>	Soil nutrient and hydrologic cycling processes are functioning at near site-potential levels, and the ability of the soil to maintain resource values and sustain outputs is high in the majority of the watershed.	Soil nutrient and hydrologic cycling processes are impaired and the ability of the soil to maintain resource values and sustain outputs is compromised in 5 to 25% of the watershed.	Soil nutrient and hydrologic cycling processes are impaired and the ability of the soil to maintain resource values and sustain outputs is compromised in more than 25% of the watershed.
<b>Soil Erosion</b>	Evidence of accelerated surface erosion is generally absent over the majority of the watershed.	Evidence of accelerated surface erosion occurs over less than 10% of the watershed, or rills and gullies are present but are generally small, disconnected, poorly defined, and not connected into any pattern.	Evidence of accelerated surface erosion occurs over more than 10% of the watershed, or rills and gullies are actively expanding, well defined, continuous, and connected in a definite pattern.
<b>Soil Contamination</b>	No substantial areas of soil contamination in the watershed exist. When atmospheric deposition is a source of contamination, sulfur and/or nitrogen deposition is more than 10% below the terrestrial critical load.	Limited areas of soil contamination may be present, but they do not have a substantial effect on overall soil quality. When atmospheric deposition is a source of contamination, sulfur and/or nitrogen deposition is 0 to 10% below the terrestrial critical load.	Extensive areas of soil contamination may be present. When atmospheric deposition is a source of contamination, sulfur and/or nitrogen deposition is above the terrestrial critical load.
<b>Rating of HUC12 for soil resources</b>	All other HUC 12s within project area for soil resources are “Functioning Properly”	<b>*Camp Creek</b> <b>*Little Snake River-Whiskey Creek</b>	No HUC 12s within project area for soil resources are “Impaired Function”

**Note:** Table is taken from Watershed Classification Technical Guide (2011).

## Overview of the Proposed Action

- Stand initiating or even-aged treatment methods would not exceed 95,000 acres.
- Uneven-aged or intermediate treatments would not exceed 165,000 acres.
- Other vegetation treatments including prescribed fire, mastication, and hand thinning would not exceed 100,000 acres.
- Cutting trees or shrubs using a variety of treatment methods including, but not limited to, clearcutting/coppice; group and individual tree selection; salvage; mastication; sanitation; and thinning.
- Cutting trees that have encroached on grass and shrub lands to maintain desired species dominance and improve wildlife habitat.

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- Prescribed burning areas using jackpot, pile burning, and broadcast burning. Maintenance burns on previously treated areas would occur to maintain desired fuels or habitat conditions.
  - Prescribed burning or tree/shrub cutting on portions of inventoried roadless areas (IRAs) (see Map 5 and Figure 10 for more information). The TOAs in IRAs were proposed by Cooperating Agencies and the Forest Service to protect communities at risk; threatened, endangered, and sensitive wildlife habitat; critical infrastructure including fences and ditches; and municipal water supplies.
  - No new permanent or temporary road construction would occur in IRAs.
  - Tree clearing and/or removal along critical linear structure including fences, ditches, and utilities;
  - Utilizing and/or reconstructing existing open and closed NFS roads to access treatment units. Reconstruction may include road blading, culvert installation or replacement, and gravelling. Closed NFS roads would be for administrative access only (i.e., they will be managed as closed to the public) and would be returned to a closed status with the method of closure being determined at implementation.
  - Constructing not more than 600 miles of temporary road, as necessary, to access treatment areas. The final assessment of road needs has not been determined and could be more or less.
  - While open, temporary roads would be for administrative use only (i.e., they would be managed as closed to the public). Temporary roads would be decommissioned following treatment activities to preclude future motorized use and to restore ecological function; decommissioning returns a road to a natural state.
  - Methods for temporary or system road decommissioning may include, but are not limited to, re-contouring the road, ripping/scarifying the roadbed, removing culverts, installing drainage features, creating physical barriers to preclude motorized travel, scattering wood/rock debris onto the road, applying seed and mulch to the area, and posting signs.
  - Developing checklists, standards, protocols, and monitoring requirements in the environmental impact statement to guide project implementation, including:
    - Complete all required surveys for each individual treatment area; complete required layout and marking of each treatment area; determine appropriate design features to be applied; and document compliance with requirements of the environmental impact statement using a set of pre-established field checklists.
    - Perform monitoring during and following implementation of individual treatment activities to ensure treatments are implemented as planned and that project objectives are met.
    - Establish an annual monitoring review with interested stakeholders, partners, and collaborative groups to ensure treatments are implemented as planned and that project objectives are being attained.
  - Using a combination of commercial timber sales, service contracts, stewardship contracts, cooperative authorities, partner capacity, and Forest Service crews to implement the project.
  - Conducting regeneration surveys, noxious weed control, native grass seeding, and road maintenance associated with implementing vegetation treatments.
  - Treatments would be authorized for a 10-year period beginning in 2018 and would be completed within approximately 15 years of the project decision.

During LAVA implementation, site-specificity will be further enhanced by completion and approval of mandatory field review forms prior to execution of individual treatments. This review process will result in the delineation of treatment activities, including temporary road locations, if necessary, and

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identification of project design features that will be applied to minimize impacts to important forest resources.

## Project Best Management Practices, Mitigation Measures, and Design Criteria

Project design features (PDFs) for this project consist of best management practices (BMPs) from the Forest Service National Core BMP document and from Forest Plan requirements (USDA 2006 and 2012). Additional PDFs were developed to address reduction of effects from mechanical activity during wet periods, skid trails and landing rehabilitation, as well as prescribed fire. This information is contained in appendix A of this document.

Throughout the Forest Service, BMPs have been developed over time based on research, monitoring, and modification, to ensure the measures are effective (Burroughs and King 1989, Burroughs 1990, Seyedbagheri 1996, Schuler and Briggs 2000). The use of BMPs is required to protect soil quality by the Forest Service as they have proven to be reliable and effective (USDA 2012) The following BMPs are to be followed for this project to ensure conservation of soil productivity into the future. They include:

- **Fire-2. Use of Prescribed Fire** (Avoid, minimize, or mitigate adverse effects of prescribed fire and associated activities on soil, water quality, and riparian resources that may result from excessive soil disturbance as well as inputs of ash, sediment, nutrients, and debris.)
- **Fire-4. Wildland Fire Suppression Damage Rehabilitation** (Rehabilitate watershed features and functions damaged by fire control and suppression related activities to avoid, minimize, or mitigate long-term adverse effects to soil, water quality, and riparian resources.)
- **Road-2. Road Location and Design** (Locate and design roads to avoid, minimize, or mitigate adverse effects to soil, water quality, and riparian resources.)
- **Road-3. Road Construction and Reconstruction** (Avoid or minimize adverse effects to soil, water quality, and riparian resources from erosion, sediment, and other pollutant delivery during road construction or reconstruction.)
- **Road-4. Road Operations and Maintenance** (Avoid, minimize, or mitigate adverse effects to soil, water quality, and riparian resources by controlling road use and operations and providing adequate and appropriate maintenance to minimize sediment production and other pollutants during the useful life of the road.)
- **Veg-1. Vegetation Management Planning** (Use the applicable vegetation management planning processes to develop measures to avoid, minimize, or mitigate adverse effects to soil, water quality, and riparian resources during mechanical vegetation treatment activities.)
- **Veg-2. Erosion Prevention and Control** (Avoid, minimize, or mitigate adverse effects to soil, water quality, and riparian resources by implementing measures to control surface erosion, gully formation, mass slope failure, and resulting sediment movement before, during, and after mechanical vegetation treatments.)
- **Veg-4. Ground-Based Skidding and Yarding Operations** (Avoid, minimize, or mitigate adverse effects to soil, water quality, and riparian resources during ground-based skidding and yarding operations by minimizing site disturbance and controlling the introduction of sediment, nutrients, and chemical pollutants to waterbodies.)

- **Veg-6. Landings** (Avoid, minimize, or mitigate adverse effects to soil, water quality, and riparian resources from the construction and use of log landings.)
- **Veg-7. Winter Logging** (Avoid, minimize, or mitigate adverse effects to soil, water quality, and riparian resources from winter logging activities.)

The following design criteria for soil resources were developed by the IDT.

<b>SOILS</b>	
<b>OBJECTIVE:</b> Minimize disturbances to soil properties (physical, chemical, and biological) to ensure inherent ecological capacity and hydrologic functions of the soil resources are maintained.	
#1	When logging occurs over snow or frozen ground: <ul style="list-style-type: none"> <li>• Harvest when frozen soil is &gt;4 inches deep OR snow or a combination of compactable snow and frozen soil &gt;12 inches thick. Snow quality should be such that it will compact and form a running surface for equipment by being moist and non-granular.</li> <li>• Additional site-specific implementation measures may be developed to minimize resource concerns, if necessary.</li> </ul>
#2	Prohibit soil-disturbing activities on slopes greater than 60% and on soils susceptible to high erosion and geologic hazard. Site-specific measures will be developed if these features cannot be avoided.
#3	For mechanical treatment maintain, at a minimum, 60% effective ground cover throughout project implementation to provide for long-term levels of organic matter and nutrients and to provide for erosion control.
#4	Site-specific project design criteria will be developed if treatment activities include operation of heavy equipment on slopes greater than 40%.
#5	Designated skid trails would be used, when applicable, during timber harvests. Designated skid trails are recommended if more than 3 passes are needed or when not on flat ground. Designated trails are not necessary when harvesting over frozen ground and or snow.
#6	Where feasible, skid trails and landings from past harvests are to be utilized to minimize new soil disturbances.
#7	Equipment operation shall not occur when ground conditions are such that extensive damage will result. If ruts develop that are 6 inch depth x 30 feet length then activities should stop.

## Required Monitoring

There is no required soil monitoring included with this project. It is highly recommended that the Soil Disturbance protocol (Page-Dumroese et al. 2009) or other soil condition evaluation be completed after project implementation to assess soil functions to ensure that soil quality has been maintained or enhanced. Also to ensure treatments were implemented as planned and project objectives were attained. If monitoring does not occur there is no documentation that soil quality, and therefore soil productivity, has been protected and that the treatments were implemented as planned and project objectives were attained.

## Environmental Consequences

### Alternative 1 – No Action

Under the no-action alternative, no timber harvesting, vegetation treatments, or fuel reduction treatments would be implemented. There would be no new disturbance resulting from project activities, and any existing disturbance would persist. No additional compaction would occur and old disturbance in the project area would continue to recover at natural rates. No new adverse effects on soils would occur from this action.

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Under the no-action alternative, the forest canopy would not be altered and organic material covering the soil would not be disturbed by management. Litter/duff layer would likely continue to thicken and increase in continuity. Coarse woody debris levels are also likely to continue to increase. As a result, erosion hazards would remain low and soil nutrient cycles would be maintained.

A high-severity fire is not certain to occur within the project area during a given timeframe. However, when a fire breaks out, the chances for high-severity fire effects on soils can be much higher in untreated areas with excessively heavy fuel loads compared to those that have successfully completed treatment, including post-harvest logging slash (Certini 2005; Graham et al. 2004; Gorman 2003; Keane et al. 2002).

The occurrence of a high-intensity wildfire would have an increased potential for impacts to soils and soil productivity in severely burned areas, especially since the risk of soil erosion increases proportionally with fire intensity (Megahan 1990). Other effects would include the potential loss of organics, loss of nutrients, and a reduction of water infiltration (Wells et al. 1979). High surface temperatures from high severity wildfire, particularly when soil moisture is low, result in an almost complete loss of soil microbial populations, woody debris, and the protective duff and litter layer over mineral soil (Hungerford 1991; Neary et al. 2005). Nutrients stored in the organic layer (such as potassium and nitrogen) can also be lost or reduced through volatilization and as fly ash (DeBano 1991; DeBano et al. 1999; Amaranthus et al. 1989).

## **Alternative 2 – Proposed Action**

Alternative 2 has the potential to affect soil functions through: 1) erosion from vegetation treatment and prescribed fire activities; 2) compaction from mechanical harvest equipment and temporary road construction; and 3) changing overall soil properties with removal of surface vegetation with implementation of prescribed fire treatments and vegetation treatments. Because of the various proposed treatment scenarios within each activity unit, and the scale of the project, the following sections describe a range of potential effects to soils for this project. Table 13 summarizes the resource indicators for the analysis.

Effects associated with this project that may reduce soil quality and lead to reduced soil functions in localized areas include:

- Compaction
- Rutting and displacement
- Severely burned soils
- Degradation of the litter layer and soil organic matter caused by increased decomposition rates and lack of appropriate annual litter contributions
- Lack of coarse woody debris
- Possible invasive plant species incursions (see the Botany specialist report for more details)

## **Direct and Indirect Effects - Alternative 2**

### *Soil Condition*

#### **Mechanical Vegetation Treatments (ground-based harvesting and mastication)**

Ground-based mechanical harvest and thinning is proposed for this project. Vegetation treatments that involve the use of ground disturbing equipment create the potential to impact soil resources by displacing and decreasing vegetative ground cover, especially in units to be clear cut, causing compaction, and

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removing overstory vegetation cover thus exposing more soil to rain impact. This could negatively impact soil functions by disrupting nutrient cycling capability and increasing runoff and erosion rates.

Soil compaction decreases total pore space in the soil, decreases water infiltration rates, and gas exchange, all of which are important for healthy functioning soil. Most soil erosion comes from skid trails, temporary roads, and landings where bare mineral soil is exposed. However, potential soil damage would be largely mitigated through the implementation of best management practices. The use of litter and woody debris on these areas has been shown to reduce erosion and sedimentation rates (Han 2009; Cram et al. 2007; Page-Dumroese 2010).

Detrimental effects from landing construction and skid trails could include soil compaction, litter loss, loss of coarse woody debris, increased potential for erosion, nutrient losses, loss of soil hydrologic and biologic function and possible invasive plant species incursions. Landings should be located on flat areas away from streams and outside or on the edge of the cutting units. New landing construction is considered to be additional detrimental soil disturbance because of altered soil horizons and structure, the burning of large piles on these landings, and limited ability to restore soils when down into the mineral soil. Where feasible existing landings and skid trails would be reused. Where existing landings are re-used, additional disturbance from this project would not occur or would be minimal (soil design criteria 5 and 6). Existing landings sometimes receive minor blading or small tree removal in order to prepare them for use. Erosion control measures would be used if needed to avoid movement from landing sites during maintenance and construction therefore resulting sedimentation is expected to be minimal. In landings larger than 1 acre, recovery would be long term, greater than 40 to 60 years, as the forest floor redevelops.

Managing soil wetness is the most important factor in rating the susceptibility of soils to soil compaction and surface disturbance (Block 2002). Some degree of soil compaction is expected to occur over 10 to 15 percent of the mechanical vegetation treatment units; best management practice monitoring has showed this result (Jagow 1994; Fleishman 1996, 2005). Most soils within the activity areas are coarse textured sand and sandy loams and therefore are more resistant to compaction and rutting. Approximately 152,040 acres have an inherent wetness rating of 5 or above within the 14 Accounting Units (Table 13; map in project file). A rating of 5 includes seasonally wet soils. Soil wetness increases with higher ratings. These acres would be most at risk for compaction, rutting, and displacement. Timber operations would occur under dry soil conditions or when the soils are frozen and have adequate snow cover to alleviate soil compaction and rutting (Minard 2003). Soil conservation practices would be implemented to mitigate soil compaction by promoting retention of slash, monitoring soil moisture levels, and identifying the areal extent of operations (soil design criteria 1, 3, 7).

Mastication or mowing is also proposed. In the short term this would have similar impacts as timber harvesting including compaction, rutting, displacement, and loss of organic matter. Adverse impacts would be mitigated by retaining protective slash on the soil surface (soil design criteria 3). In the long term (7 to 10 years) mechanical treatments would benefit soil and watershed resources by thinning dense woody cover and providing additional vegetative ground cover for soil resources. Thinning of high woody cover would improve and maintain functional soil conditions by providing favorable conditions for increasing graminoid cover.

Vegetation treatment followed by prescribed burning would also occur to reduce surface vegetation cover on these sites. In these areas the benefit of retaining slash on site could be offset when fire is introduced to remove surface fuels. The effects would be similar to the prescribed fire discussed below. However, in clear cut units, which remove the whole tree and future nutrients to the soil, the second treatment of fire could remove much of the future nutrient input for the soil disrupting nutrient cycling and soil functions. However, the reduction of the woody canopy would promote additional vegetation ground cover

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associated with an increase of graminoid cover and this would improve soil function, provided fire is not introduced too soon.

### **Temporary Roads**

Approximately 600 miles of temporary road could be created during project implementation. Most of the negative impacts to the soil resource occurs with the creation of the road or trail itself. The road removes soil resources from the productive land base and where roads occupy formerly productive land, they affect site productivity (Gucinski et al. 2001). Losses of productivity associated with road-caused accelerated erosion are site specific and highly variable in extent (Gucinski et al. 2001). Once the road is established impacts continue through processes such as mass wasting, surface erosion, sedimentation, and creation of pioneered routes across the landscape. Geomorphic effects of roads range from chronic and long-term contributions of fine sediment into streams to catastrophic mass failures of road cuts and fills during large storms (Gucinski et al. 2001). Roads affect geomorphic processes by four primary mechanisms: accelerating erosion from the road surface and prism itself by both mass and surface erosion processes, directly affecting channel structure and geometry, altering surface flow paths, and causing interactions among water, sediment, and woody debris at engineered road-stream crossings (Gucinski et al. 2001). Areas of an inherent wetness index rating of 5 or above should be avoided or have site-specific design criteria created when a project is developed within the area.

### **Nonmechanized Vegetation Treatments**

Nonmechanized fuel treatments are proposed. This would entail hand thinning using chainsaws. Slash would be piled or scattering following treatment. Prescribed fire would also be applied to these treatment areas following thinning. Prescribed fire would have similar effects as described below in the prescribed fire section. Soil loss and disturbance would be minimal because no ground disturbing equipment would be used.

### **Prescribed Burning**

Fire alters many soil properties, including organic matter content and nutrient related processes. Organic matter is one of the most important elements in retaining soil productivity and long-term site health. Fire consumes organic matter and depending on the severity can significantly change organic matter content, and therefore, several other important aspects of soil productivity. Loss of organic matter can lead to decreases in long-term available nutrients, changes in soil structure, and losses of soil porosity (Neary et al. 2005; DeBano et al. 1999; DeBano 1991). The recovery of organic matter following fire is key to restoring ecosystems productivity and disturbing the recovery of organic matter could lead to long-term detrimental soil disturbance (Beschta et al. 2004).

The impacts of burning depend on levels of fire severity. Fire intensity and fire severity are not synonymous. Fire intensity is concerned mainly with the rate of aboveground fuel consumption and energy release rate. Fire severity is a more qualitative term used to describe the effects of fire on soil and other ecosystem resources. Severely burned soils are identified by ratings of fire severity and the effects to the soil resource (Neary 2005). The impacts of burning depend on levels of fire severity and whether prescribed fire would remove 100% of the surface fuels or result in a mosaic burn across the units. Slash piles would result in the highest severity from higher temperatures in a concentrated area. Litter and duff consumption is likely to occur at high rates in pile burns. Small piles that are spread out over a unit would minimize litter loss. Micro-sites with more fine fuel buildup would result in isolated, small patches of moderate intensity fire. Effects are significantly reduced when soil moisture levels are above 25 percent (Niehoff 2002).

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Soil nutrients most affected by fire are carbon (C) and nitrogen (N). During high severity fires large amounts of C and N can be lost. Nitrogen is mainly lost through volatilization, but can also be lost following fire from increased erosion. Ash deposited following fires contain nutrients for vegetation (Neary et al. 2005). Nitrogen fixing plant species are commonly found in post-fire environments and increase nitrogen in these ecosystems following fire (DeLuca and Zouhar 2001). Fires can also change the form of nutrients and make some nutrients more available (Neary et al. 2005). Nitrogen availability could increase for a short period of time following fire (Choromanska and DeLuca 2002). Following fire, there is an increase in down woody debris on the forest floor that helps recycle carbon and increase nutrients for vegetation colonizing sites following fire. Generally, if plants colonize sites following fire, nutrient levels can reach pre-fire levels quickly (Certini 2005). Charcoal deposited following fire also adds carbon to the soil (DeLuca and Aplet 2008). Soil microorganisms are also affected by fire, but recoup fairly quickly and recolonization to preburn levels is common (Neary et al. 2005). Soil bacteria and fungi, important components to nutrient cycling and over soil productivity, have been found to be resistant to fire impacts (Jennings et al. 2012) and likely recover very quickly.

Prescribed fire can increase available nitrogen for 1 to 2 years (Choromanska and DeLuca 2002). Burning slash piles could create extremely high temperatures in concentrated areas and would lead to volatilization of nitrogen and loss of phosphorus and potassium (DeBano 1981). If litter layers and organic matter are kept intact throughout the rest of the stand, nutrient losses would be minimal from burning slash and would be localized. Nitrogen-fixing plants can colonize sites following fire and help restore nitrogen in the ecosystem (Newland and DeLuca 2000; Jurgensen et al. 1997). Following fire, soil erosion can increase, which could also reduce the nutrient pool (Megahan 1990). Generally, if plants colonize sites following fire, nutrient levels can reach pre-fire levels quickly (Certini 2005). Charcoal deposited following fire also adds carbon to the soil (DeLuca and Aplet 2008).

Indirect effects of soil nutrient loss include reduced growth and yield and increased susceptibility to pathogens, such as root disease (Garrison and Moore 1998; Garrison-Johnston et al. 2003) and insect infestation (Garrison-Johnston et al. 2003 and 2004).

Prescribed fires can also result in a positive response through improving soil functions; by expediting nutrient cycling, decreasing woody canopy cover, improving herbaceous response, and improving overall vegetative ground cover which improves soil stability. Dense shrub cover would decrease resulting in an increase of graminoid cover and total vegetative cover that would improve hydrologic processes, stabilize the soils, and assist in improving nutrient cycling. Prescribed burning typically results in a positive benefit to soil resources with a mosaic pattern of burned and unburned ground and predominately low severity burn. Litter and shrub canopy would not be fully consumed but dense shrub cover would decrease resulting in an increase of graminoid cover and total vegetative cover that would improve hydrologic processes, stabilize the soils, and assist in improving nutrient cycling.

All of the soil units subjected to prescribed fire would show an increase of soil loss and future nutrient input from current conditions because there would be a decrease in ground cover and increase in erosion. Approximately 62,526 acres within the 14 accounting units have an Inherent Index Rating of 1 and 2. These ratings are for dry sites that are on south/southwest aspects and with steeper slopes. In addition approximately 59,094 acres of shallow soil exist within the 14 accounting units. These acres would be areas of concern for soil resources due to the greater damage to the soil that would occur if surface organic material was removed.

The prescribed burn is designed to be a low to moderate intensity and low to moderate severity fire based on parameters specified in the prescribed burn plan. Generally, negative impacts to the soil resources would be short lived (i.e., 2 to 7 years) because prescriptions would occur during favorable burn periods (e.g., favorable weather conditions and planned burn blocks resulting in favorable fire behavior) and best

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management practices would be implemented (Neary 2005). Positive impacts to the soil resources would be variable, but extend to 3 to 10 years. The actual degree of accelerated soil loss impacts is variable and dependent on the differing soil characteristics and ecotypes.

### *Erosion Hazard*

#### **Mechanical Treatments**

During mechanical (ground-based) harvesting ground cover would be displaced or removed. Skid trails and landing would create compacted, displaced, and rutted areas predicted to occur on up to 15 percent of mechanically treated areas. Where mineral soil is exposed surface runoff increases. In many areas, vegetation treatments followed by prescribed fire would open up canopies creating an environment more conducive to plant growth, which ultimately would further decrease soil loss in the long term.

There are approximately 33,747 acres of soils with severe erosion hazard. There are approximately 112,300 acres within the accounting units that have severe mass wasting potential (Table 13; map in project file). Moderate or severe erosion hazard ratings do indicate that if soils are bared, erosion would likely occur and site productivity would be affected. Implementing all appropriate resource protection measures and best management practices in these locations would be extremely important in order to maintain or improve vegetative ground cover and reduce soil loss (soil design criteria 2, 3, and 4).

#### **Prescribed Fire**

Prescribed fire is expected to decrease shrub cover and increase graminoid cover, increasing the ability of the soil to resist erosion. The duff and litter layer is important in protecting the soil horizons, both as reducing erosion potential and in maintaining soil moisture and this is especially important on steep slopes. Litter prevents the breakdown of soil aggregates and lessens the velocity of any overland flow, thereby decreasing the erosion potential. Keeping duff and litter layers intact would help to reduce erosion. In areas where erosion rates are above tolerable levels increasing ground cover is especially important and returning these sites to states in which graminoid cover is increased may trend these sites towards reduced soil loss and erosional rates in the future.

Because of higher soil and duff moisture expected during burning, we anticipate areas of exposed mineral soil to be limited and scattered after the burn (Soil BMPs Fire 2 and 4). Large-scale detrimental erosion from prescribed fire is not anticipated. Localized minor erosion, which would not impact the overall soil productivity of the area, is expected.

Temporary road, landing and other road work impacts to soil stability and soil erosion are discussed above.

### *Organic Matter and Vegetative Ground Cover*

Harvest operations remove biomass and other site organic matter which affects nutrient cycling. Generally, nutrient losses are proportional to the volume of biomass removed from a site. Nutrients are lost during harvesting by removing the stored nutrients in trees, and additional nutrients are lost if the litter layer and woody debris are removed. Whole-tree harvesting, which extracts larger amounts of biomass, especially the nutrient-rich foliage, compared to conventional sawlog or thinning operations, removes a larger amount of the nutrients from the site. The exact amount of nutrients lost from a particular site would vary with forest types and particular site conditions (Grier et al. 1989). The amount of nutrients present in the trees would also vary with stand age and development of the humus layer (Grier et al. 1989). Moreover, the greater the proportion of nutrients stored in trees, the greater the potential for site degradation and declines in productivity after harvesting operations. The data suggest that nutrient

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losses from whole-tree harvesting are considerably greater when compared to conventional sawlog harvesting for all nutrients. Calcium losses were particularly large for whole-tree harvesting due to the high concentrations of calcium present in the wood fiber of twigs, branches, and boles (Adams 1998; Mann et al. 1988). Organic matter is especially important for retaining nutrients, increasing water holding capacity, and erosion control (DeBano 1991; Page-Dumroese 1991). On steeper slopes (greater than 40 percent), if harvesting is proposed, utilizing a slash mat and retaining slash on site would preserve the nutrients on site and reduce the potential for reduced productivity over time (Cram et al. 2007; Zamora et al. 2014).

The importance of maintaining soil organic matter cannot be overstated (Okinarian 1996; Jurgensen et al. 1997). This organic component contains a large reserve of nutrients and carbon, and it is dynamically alive with microbial activity. The character of forest soil organic matter influences many critical ecosystem processes, such as the formation of soil structure, which in turn influences soil gas exchange, soil water infiltration rates, and soil water-holding capacity. Soil organic matter is also the primary location of nutrient recycling and humus formation, which enhances soil cation exchange capacity and overall productivity. Vegetative ground cover consists of dead plant material (litter) and live vegetation that is in contact with the soil surface and is important in development of soil organic matter. This cover is important in maintenance of soil on site.

These processes have direct and tremendous effect on site productivity and sustainability. Organic matter is the one component of the soil resource that, if managed correctly, can actually be improved by human activity. Manipulation of the organic constituents of the soil may be the only practical tool available for mitigating effects of harvesting systems that remove standing trees and dead and down trees, or cause extensive soil disturbance. To protect the sustainable productivity of the forest soil, a continuous supply of organic materials must be provided. Maintaining or increasing organic matter will aid in keeping soils functioning properly. 621,467 acres within the 14 accounting units have a surface organic matter percentage of 0.5 or lower. This figure does not distinguish between vegetation types that may be low by their natural state or bare areas. Many of these soils are young Entisols and may not have had time necessary to build organic matter. But it does emphasize the need to maintain organic matter on site for future nutrient cycling and enhancing site productivity.

Following fire, soil erosion can increase, which could also reduce the nutrient pool (Megahan 1990). Ground cover and coarse woody debris would be important components within these areas following treatment in order to reduce erosional processes and potential loss of organic matter. Generally, if plants colonize sites following fire, nutrient levels can reach pre-fire levels quickly (Certini 2005). Charcoal deposited following fire also adds carbon to the soil (DeLuca and Aplet 2008). Prescribed burning is anticipated to occur during times of higher soil moisture, further protecting the organic matter present.

Potential indirect long-term effects of soil nutrient loss include reduced growth and yield and increased susceptibility to pathogens, such as root disease (Garrison and Moore 1998; Garrison-Johnston 2003) and insect infestation (Garrison-Johnston et al. 2003, 2004). Annual needle, leaf, and twig fall; forbs; and shrub mortality will continue to recycle nutrients.

Approximately 62,526 acres within the 14 accounting units have an Inherent Index Rating of 1 and 2. These ratings are for dry sites that are on southern aspects and with steeper slopes. In addition, approximately 59,094 acres of shallow soil exist within the 14 accounting units. These acres would be areas of concern for soil resources and areas to keep organic matter on the soil due to the greater damage to the soil that would occur if surface organic material was removed.

**Table 12: Resource indicator acres within the 14 accounting units**

	Indicator – Soil Condition		Indicator – Erosion			Indicator Organic Matter
Accounting Unit	Inherent Wetness Index (Rating Values 5+) Acres	Inherent Wetness Index (Rating Values 1 and 2) Acres	Erosion Hazard Acres	Mass Wasting Acres	Soil Depth Acres	Organic Matter Acres
Battle Pass	11,770	7,724	2,404	7,643	3,271	31,568
Big Blackhall	24,283	4,958	521	8,230	420	47,954
Bow Kettle	14,545	13,956	1,320	4,952	1,132	58,407
Cedar Brush	4,909	3,951	117	5,556	2,790	48,405
Foxwood	22,372	5,535	0	8,708	5,121	66,566
French Douglas	6,626	4,556	2,743	7,360	8,040	55,084
Green Hog	10,686	2,886	5,536	16,921	6,625	47,112
Jack Savery	9,628	2,829	2,095	16,396	4,266	40,638
North Corner	1,971	2,739	118	3,572	529	37,102
Owen Sheep	13,875	1,587	5,508	1,586	11,461	13,302
Pelton Platte	7,968	1,831	0	3,223	10,537	32,860
Rock Morgan	4,818	2,120	5,722	3,565	78	53,782
Sandy Battle	12,919	3,846	7,764	17,552	1,650	37,621
West French	5,670	4,018	1,219	7,036	3,174	5,106
<b>Totals</b>	<b>152,040</b>	<b>62,526</b>	<b>33,747</b>	<b>112,300</b>	<b>59,094</b>	<b>621,467</b>

**Table 13. Resource indicators and measures for alternative 2 (proposed action)**

Resource Element	Resource Indicator	Measure	(Alternative 2)
Soil Disturbance, Soil Stability	Soil Condition	*Acres of 5+ Inherent Wetness Index rating (soil disturbances) *Acres of 1 and 2 Inherent Wetness Index rating (prescribed fire)	*152,040 acres *62,526 acres
Soil Stability	Erosive soils	*Acres of "severe" erosion hazard *Acres of "severe" mass wasting hazard	*33,747 *112,300
Soil Quality Soil Productivity	Organic Matter Soil Condition	Shallow soils	59,094
Soil Quality	Organic Matter Soil Condition	Acres of low surface organic matter (0.5%)	621,467

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## Cumulative Effects – Alternative 2

Legacy soil disturbance that has occurred as a result of past activities forms the foundations of the soil condition on the landscape today. Past and current activities within the project area that could be considered detrimental to the soil resource have been accounted for in the existing conditions section of this document.

### **Mechanical Treatments**

Timber harvests have occurred in the past within the Accounting Units. Depending on when and where timber harvests and vegetation treatments are located during LaVa implementation there could be cumulative effects to soil productivity could occur if soil recovery has not occurred from previous harvesting activities. Resource protection measures and best management practices would be implemented in order to maintain soil productivity, organic matter, and soil stability on these sites. Coarse woody debris would be maintained along with ground cover and further treatments would be postponed if soil recovery has not occurred. Previous disturbed areas would be utilized to the extent possible to minimize further soil damage.

### **Wildfire and Fire Suppression**

The proposed thinning would reduce future potential fire behavior. The benefits of fires with lower intensity and severity would include a reduced potential of excessive soil heating and sterilization as well as the development of hydrophobic conditions that tend to increase sediment movement, flooding, and possible slope instability (de Dios Benavides-Soloria and McDonald 2005; Neary et al. 2005).

On small wildfires, disturbance from fire suppression activities is usually limited to hand tools; most hand fire-line construction has only minor (insignificant) impacts to the soil resource. Machine line using heavy equipment is also built during wildfire suppression. These machine lines are rehabilitated following suppression activities. During fire suppression, closed roads may be reopened for access and incorporated as fire line. As part of the post-fire work, the areas of disturbance are rehabilitated and the roads returned to their previous condition in most cases. There is potential for some cumulative effects to soils if suppression activities occur in areas where soil disturbance has occurred from project implementation and may slow soil recover in these limited areas over time.

### **Recreation**

Disturbance from general motorized use and recreational access has been occurring and would continue throughout the units indefinitely. We anticipate no changes in the existing recreation profile. Other recreational activities that occur off the developed roads, such as the gathering of miscellaneous forest products and hunting, are occurring in the project area. Closing skid trails in this area following treatment should prevent this occurrence and should not have additional effects on soils in the project area. Cumulative effects to soils from recreational vehicle use are not expected. See the Recreation and Areas with Special Designation specialist report for further discussion on recreational vehicle use.

### **Grazing**

There are grazing allotments within the entire area of the 14 Accounting Units. The proposed treatment units would be subject to cumulative grazing impacts within the active allotment boundaries. Impacts of grazing are limited to areas where the animals bed, lounge, trail, or access water. These areas are generally small in aerial extent. Impacts include compaction, removal of groundcover, and displacement. Grazing would continue in the foreseeable future on these allotments. Generally, compaction is limited to the grassland portions of harvest stands so effects of cattle do not overlap in space with the harvesting treatment units; however, within the mastication treatment areas where graminoid cover may increase

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following treatments, cumulative impacts from grazing to the soil resource are possible. Cattle may maintain compaction in localized lounging and trailing areas, decreasing the soil recovery on portions of the treated areas. Grazing following prescribed burning could potentially have detrimental soil impacts, but resting prescribed burn units for a time should alleviate cumulative effects from grazing as soils and vegetation would have time to recover.

### **Road Maintenance**

All developed roads built in the past have a long-term effect on soil productivity due to compaction and displacement. Their maintenance for residence access, recreation, and forest management calls for ongoing use, which results in compaction and displacement through the project area.

Road maintenance includes culvert installation, blading, and brushing, and typically improves drainage and decreases erosion from water channeling down the road surface in the long run. See the Hydrology specialist report for a detailed analysis and information on roads and related issues. Cumulative effects are not expected from road maintenance activities.

## **Summary**

The LaVa Restoration Project would comply with the Medicine Bow National Forest Land and Resource Management Plan for long-term soil productivity for the proposed treatments. The proposed harvesting and fuels reduction treatments are not expected to adversely affect the soil resource because of resource protection measures that would be implemented as part of the proposed action alternative. Site-specific resource protection measures would help to ensure that ground cover is preserved and the soil resource is adequately protected during the project implementation stage. Some increases in erosion are expected to occur following prescribed burning, but these increases are expected to be short term. Organic matter and ground cover would be protected and soils that are in unsatisfactory or impaired conditions currently would trend towards satisfactory condition over time with the implementation of the restoration project. Soils with impaired or unsatisfactory condition are not expected to be further impaired by the proposed activities.

Under the no-action alternative, no timber harvesting, vegetation treatments, or fuel reduction treatments would be implemented. There would be no new disturbance resulting from project activities, and any existing disturbance would persist. No additional compaction would occur and old disturbance in the project area would continue to recover at natural rates. No new adverse effects on soils would occur from this action.

Under alternative 2 (proposed action) generally, all the negative impacts to the soil and watershed resources would be short lived (i.e., 2 to 7 years and 4 to 10 years) and be minimized through the implementation of soil and water resource protection measures. Some treatments may have an indirect positive impact to the soil resources while other treatments are designed to improve and restore the soil and watershed resources. Positive impacts to the soil and watershed resources are expected to extend to 3 to 10 years.

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## Compliance with LRMP and Other Relevant Laws, Regulations, Policies and Plans

### Land and Resource Management Plan

Implementation of Forest Service BMPs and project design features would ensure compliance with the Medicine Bow National Forest Land and Resource Management Plan (LRMP), as well as Forest Service Manual 2500, Chapter 2550 – Soil Management.

### Short-term Uses and Long-term Productivity

Short-term uses that affect the soil resource long-term productivity were discussed in the environmental consequences section. Short term uses include temporary road creation for timber harvesting and other vegetation treatments, landing and staging areas for timber harvests, and prescribed fire effects.

Effects to soil resources are short term (2-7 years) and long term (greater than 10 years). Positive impacts to the soil and watershed resources are expected to extend to 3 to 10 years.

### Unavoidable Adverse Effects

There are no unavoidable adverse effects to soil resources with this project.

### Irreversible and Irretrievable Commitments of Resources

Irreversible commitment of resources describes the loss of future options. This applies primarily to the effects of use of nonrenewable resources, such as minerals or cultural resources, or to those factors, such as soil productivity that are renewable only over long periods of time. Irretrievable commitments are those that are lost for a period of time such as the temporary loss of timber productivity in forested areas that are kept clear for use as a power line right-of-way or road.

An irretrievable commitment of soil resource is expected to occur where temporary roads are created or have been created until they are removed from the landscape. Potential areas within prescribed burning operations could also become an irretrievable commitment of soil resources where erosion increases beyond tolerable limits, especially on shallow soils, as this would cause a temporary loss of timber productivity and habitat productivity. With the appropriate use of Design Criteria, BMPs, and watershed conservation practices, no irreversible impacts are anticipated. Roads and trails can be obliterated and hydrologically restored.

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## **Appendix A**

Inherent Wetness Index Ratings Maps by Accounting Unit

See project file for maps